Virtual Worlds at the University of North Carolina at Chapel Hill

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The Ultimate Display

Ivan Sutherland, 1965 (Proc. of IFIP Congress):

"the task of the display is to serve as a looking-glass into the mathematical wonderland constructed in computer memory"

"the ultimate display would be a room within which the computer can control the existence of matter"

1968 (AFIPS Conference Proceedings):

reported first working virtual-environment system

"Is that you, or am I experiencing Artificial Reality?"

Underlying Technologies

- computer image generation

realistic rendering
high frame rates
low latency

- tracking (head, hands, etc.)

6 degrees of freedom
large working volume
update rate matching image generation, with low latency

- head-mounted display

comfortable
color
wide field of view
high resolution
stereoscopic

Other Questions

- human perceptual psychology
- real-time software
- difficult to study these while underlying hardware technologies are still so primitive

Image Generation

- most strongly driven by economic pressures
- numerous companies now produce systems with "real-time" performance
- but considerably higher performance is required for real-world applications

Pixel-Planes Graphics Engine

- a VLSI-based, massively parallel architecture for high-speed rendering of 3D objects and scenes

- basic idea - build the frame buffer from custom logic-enhanced memory chips, which provide:

    1) a distributed linear expression evaluator which provides Ax + By + C simultaneously to every pixel
    2) a tiny processor *per* pixel
    3) very high bandwidth between these processors and the pixel memory

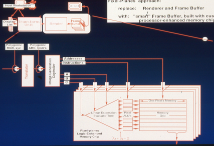
- a number of prototypes have been built, including two full-scale systems: Pixel-Planes 4 and Pixel-Planes 5

Pixel-Planes 4

Pixel-Planes approach:

replace: Renderer and Frame Buffer

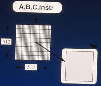
with: "smart" Frame Buffer, built with custom processor-enhanced memory chips



Evolution to Pixel-Planes 5

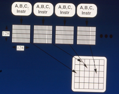
Pixel-Planes 4

A single, screen-sized computing surface locked 1:1 to screen pixels.



Pixel-Planes 5

Multiple, small, independent computing surfaces flexibly mapped to the screen.



Increase performance linearly, simply by adding more computing surfaces

Pixel-Planes 5

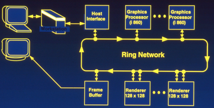
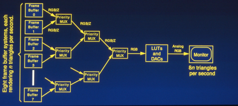


Image Composition Architecture

- proposed (independently) by Molnar and Shaw
- allows virtually unlimited performance increase with linear increase in hardware and negligible increase in latency



Tracking Requirements

- fast update, and low latency
- high accuracy
  translational: about 1 millimeter
  rotational: about 0.1 degrees
- large working volume: room-sized, perhaps outdoors !
- allow tracking more than one target (head and hand)
- compact, comfortable (lightweight and unrestrictive)
- impose minimum restriction on the environment

Present State of Tracking

- Polhemus is used by virtually everyone
- Ascension (Bird) claims improvements
- advantages:
  does not require clear line of sight (like optical)
  easy to set up
  light weight
- disadvantages:
  limited working volume (1 meter hemisphere)
  sensitivity to metal in the environment (spatial distortion)
  sensitivity to AC magnetic fields (jittering)
  slow update rate and long latency
- note: not all these faults are inherent in the magnetic approach

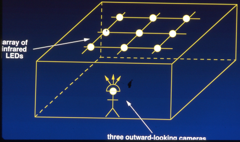
Approaches to Tracking

- **mechanical**
  - used in Sutherland's first system
  - working range limited by mechanical linkage
  - difficult to track several objects
- **acoustic (Lincoln Wand)**
  - speed of sound limits update rate * working volume
  - air density variations limit accuracy
- **magnetic (Polhemus, Ascension)**
- **inertial**
  - suffers from poor stability (drift)
  - requires no line of sight
  - working volume not limited
- **optical beacon (Selspot, Optotrak)**
  - require clear line of sight
  - need several cameras with fields of view covering entire working volume

Optical Inside-Out Tracking

- first suggested by Bishop et al. in 1984
- beacons in environment, camera on user
- more sensitive to rotations
- cellular approach: working volume is infinitely extendible, by adding very cheap LEDs

Inside-Out Optical Tracker



Future Work on Tracking

- eliminate need for optical beacons, using silicon photo-sensors (Bishop's Self-Tracker)
- do servo-controlled optical tracking
- hybrid tracking schemes:
  fast low-stability inertial sensors, coupled with high-stability optical tracking

Display Gear

- most early work by military
- virtual-environment has different requirements
- we CANNOT (?) push technology of actual displays
- we CAN prototype helmets and optical systems

New UNC Head-Mount

-two 1 inch CRTs
- full or partial color
- field of view:
  60 deg each eye, 50 deg overlap, 70 deg total
- resolution:
  approximately 1000 by 1000
- see through optics, bright enough for indoor light
- allows wearing eyeglasses
- adjustable inter-pupillary distance
  (and wide *exit pupil* for optics system)